

Dynamical coupled channel approach to omega meson production

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Abstract

The dynamical coupled channel approach is applied to study the ω -meson production induced by pions and photons scattering from the proton. The parameters of the model are fixed in a two-channel ($\omega N, \pi N$) calculation for the non-resonant and resonant contributions to the T matrix by fitting the available unpolarized differential cross section data. The polarized photon beam asymmetry is predicted and compared to existing data.

1 Introduction

Nucleon resonances are thought to play a decisive role in reactions of strong, electromagnetic and weak probes on nucleons. The extent to which nucleon resonances determine both unpolarized and polarized observables remains an open question in the second and third resonance regions from center-of-mass (COM) energies, E in the range $1.4 \text{ GeV} \leq E \leq 2.0 \text{ GeV}$. A model determination of the T matrix consistent with the observed meson production data in this kinematic regime seeks to resolve the resonance structure of the nucleon. The determination of the resonance spectrum will yield insight into fundamental aspects of quantum chromodynamics, such as confinement.

In the second and third resonance regions, hannels such as ηN , $\pi\Delta$, ρN , σN , ωN and $\pi\pi N$ become important. Matsuyama, Sato, and Lee (MSL) [1] have developed a dynamical coupled channel formalism to handle any number of channels with up to three particles in intermediate and final states. In this exploratory study, we consider the ω meson production reactions, $\pi^- p \rightarrow \omega n$ and $\gamma p \rightarrow \omega p$, in a two-coupled channel $\pi N, \omega N$ formalism. A full calculation

incorporating the effect of stable ηN and unstable channels $\pi\Delta$, ρN , σN is being pursued presently.

In this study our objective is to show that it is possible (when the ω production is extended to include the four additional channels ηN , $\pi\Delta$, ρN , σN) to predict polarized observables from the model resulting from fits to the unpolarized differential cross section data.

We will briefly describe the MSL model theory for the two-channel model for πN and ωN and present results of the fit.

2 Model reaction theory

The T matrix for $\gamma N \rightarrow \omega N$ and $\pi N \rightarrow \omega N$ is separated into non-resonant, t and resonant, t^R terms

$$T(E) = t(E) + t^R(E), \quad (1)$$

where E is the scattering energy of the particles in the center-of-mass frame. The non-resonant contribution is a smooth, regular operator function of the energy while the resonant term is meromorphic in the energy. No additional assumption is made about the relative size of the contributions of these terms.

The non-resonant contribution, $t(E)$ to the full transition matrix satisfies the (relativistic) Lippmann-Schwinger (LS) equation

$$t(E) = [1 + t(E)G_0(E)]v \quad (2)$$

At leading order in the coupling constants of the Lagrangian the kernel, v is given by the Born amplitudes for pion production and photoproduction amplitudes. We neglect the contribution of the η , a_0 , and f_2 in the non-resonant terms.

The kernel depends on coupling and cutoff parameters which are varied (along with the resonance parameters, see below) to fit the observed data. The varied parameters are

$$v = v(g_{\rho NN}, \kappa_\rho, g_{\rho\pi\pi}, g_{\omega NN}, \kappa_\omega, g_{\omega\pi\rho}, \Lambda_{\pi NN}, \Lambda_{\rho NN}, \Lambda_{\rho\pi\pi}, \Lambda_{\omega NN}, \Lambda_{\omega\pi\rho}). \quad (3)$$

The remaining parameters are fixed at the SL [2] values. Form factors are assumed at each vertex. The gauge invariance is ensured only at the Born amplitude level. Inclusion of coupled channel and rescattering effects violates the gauge invariance. This is obviously an unsatisfactory aspect of the model which is hoped to nevertheless be useful in analyzing meson production reactions.

All particles, except the resonances N^* , are assumed to be stable. In particular, we neglect the width of the ω meson $\Gamma_\omega = 8.5(1)$ MeV.

The resonant contribution, $t^R(E)$ to the scattering matrix is given as

$$t^R(E) = \bar{\Gamma}(E) \frac{1}{E - H_0 - \Sigma(E)} \bar{\Gamma}(E), \quad (4)$$

where $H_0 |N^*\rangle = M_{N^*}^{(0)} |N^*\rangle$ and $\bar{\Gamma}(E)$ is the dressed vertex operator and $\Sigma(E)$ the resonance self-energy.

The resonance parameters which can be tuned to fit the experimental data are the bare masses $M_{N^*}^{(0)}$, the amplitudes G_{LSMB}^{JT} , $A_{\lambda,T_{N,z}}^{JT}$, and the cutoffs Λ_{LS}^{JT} , Λ_λ^{JT} . In practice we only use two cutoffs. One for all the strong vertices, $\Lambda_{LS}^{JT} = \Lambda_M$ and one for the electromagnetic vertices $\Lambda_\lambda^{JT} = \Lambda_\gamma$.

3 Results and discussion

The fit to the $\gamma p \rightarrow \omega p$ data is shown in Fig.(1). The simultaneous fit (not shown here) to the $\pi^- p \rightarrow \omega n$ data is of similar quality. In particular, this fit near threshold is consistent with data. The behavior near threshold appears to be described well in the current coupled channel approach [3]. The prediction for the linearly polarized photon beam asymmetry $\Sigma(\theta; E)$ is shown for $E = 1.743$ GeV in Fig.(2). Although the predicted $\Sigma(\theta; E)$ is not consistent with the data, the size and sign are correct. It is hoped that the effect of other channels such as $\pi\Delta$, ρN , etc. and possibly other resonances will help to improve the agreement.

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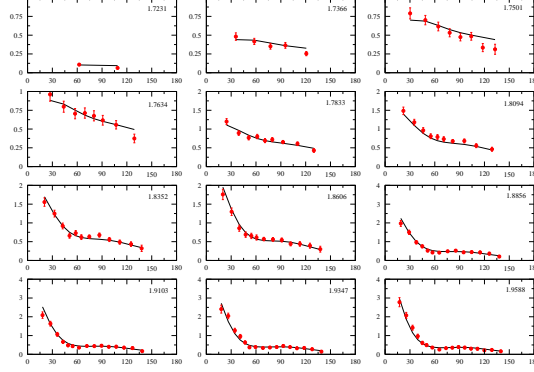


Figure 1: Observed unpolarized differential cross section [4] (circles) for $\gamma p \rightarrow \omega p$ compared to calculated values. The differential cross section, $\frac{d\sigma}{d\Omega}$ in $\mu\text{b}/\text{sr}$ is plotted against the ω emission angle, θ in the center-of-mass frame. Each panel shows the cross section for given center-of-mass energy, E in GeV in the upper-right corner.

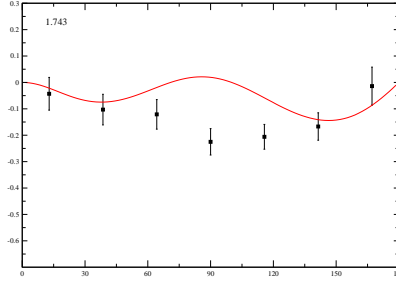


Figure 2: Photon beam asymmetry compared to data from GRAAL [5] for values of COM energy shown in the lower left-hand corner of each panel. Solid curves are for the full calculation. At energy $E = 1.743$ GeV the sensitivity to the resonance contribution is studied (see text).